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TRANSLATION

INFLUENCE OF AN ELECTRICAL FIELD ON FLAMES

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INFLUENCE OF AN ELECTRICAL FIELD ON FLAMES

A. Ye. Potapenko and P. P. Kostenko

This article was written to explain the possibility of improving the blow-off characteristic of burners by applying a constant electrical field to the flames. An entire series of tests were conducted on a nozzle burner of "pyrex" glass with an outlet diameter of 9.8 mm. A central electrode is placed inside the burner 26 mm below its rim and above the burner is placed a metal ring of 32 mm serving as the second electrode.

Ethyl alcohol was used as the fuel.

At a specific pressure the liquid fuel flowed through the jet into a tube leading the mixture to the burner where it was vaporized in an air flow. The jet fed the alcohol to a cloth filler used to improve the vaporization process. Moreover, the air fed into the burner was preheated by a coil through the wall of the tube. The preheating was regulated so that the temperature of the mixture in the center of the stream coming out of the burner equalled 100°C. Thus on the walls of the burner there was absolutely no precipitation of alcohol droplets, which is evidence of the homogeneity of the mixture.

The temperature was checked by means of a thermocouple each time after attaining blow-off of the flames. When its value deviated more than 3° from 100°C the experiment results were not used for processing the data, and the heating was adjusted accordingly.

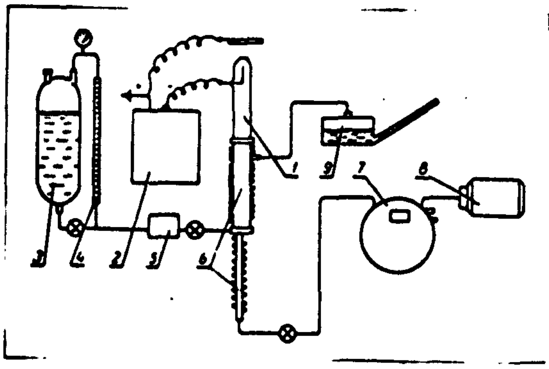

Fig. 1. Schematic of the arrangement: 1) burner; 2) high-voltage rectifier; 3) fuel tank; 4) flow meter; 5) pressure regulator; 6) mixture preheater; 7) gas meter; 8) compressor; 9) micromanometer.

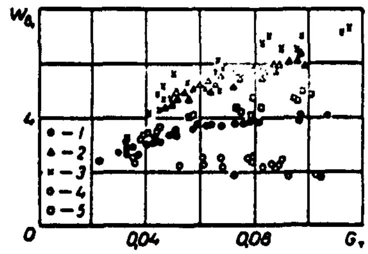

Fig. 2. Influence of a constant electrical field on flame blow-off of a mixture of C_2H_5OH - air (W_{B_1} is the blow-off velocity, m/sec; G_T is the discharge of fuel, g/sec): 1) u = 0; 2) u = = -35 kv, h = 0; 3) u = -35 kv, h = 16 mm; 4) u = 30 kv, h = 0; 5) u = 30 kv, h = 16 mm.

The fuel was fed by a pressure regulator in front of the jet and was measured by the flow tube. The flow of air was regulated by a stopcock and measured by the readings of the gas meter (Fig. 1).

The tests were conducted in the following manner. The mixture was ignited at the outlet from the burner and voltage was applied to the electrodes; then blow-off was achieved by increasing the air supply. The maximum voltages were close to breakdown voltages and reached 35 kv; the minimum test voltage was 10 kv. With the ring electrode located at the burner opening (h = 0) it appeared that application of a negative field (according to the sign of the central electrode) made necessary a significant increase in the air supply to attain a blow-off

with a given fuel flow rate. A positive charge, on the other hand, greatly impaired blow-off characteristics, removing the flame from the burner rim.

Somewhat different results were obtained by placing a ring electrode 16 mm above the burner rim (h = 16 mm). The application of a negative field in this case as well allowed the flame blow-off velocity to increase. But the influence of the positive field quite unexpectedly changed its character: instead of flame blow-off we now observed a clear improvement of the flame stability, although it is less significant compared with the effect due to application of a negative field, i.e., an increase of the velocity of its blow-off. All of these effects were proportional to the applied voltage. The test results for maximum test voltages are presented in Fig. 2.

With this arrangement an attempt was made to determine, by direct photographs of the flame front by the Michaelson method, the influence of the electrical field on the normal flame-propagation velocity. Because of the difficulty of exact determination of small angles at the top of the inner cone, calculations yield a large point scatter, but nevertheless we observe that there were no essential changes in the form of the inside cone and normal flame-propagation velocity with application of an electrical field.

Results which agreed qualitatively with the above were also obtained with the same arrangement by experimentation with gasoline. The nature of the influence of the positive field was changed in these experiments as well with an increase of the distance of the ring electrode from the burner rim. Thus, by placing the ring electrode close to the burner rim the change of field polarity led to a change of its influence on flame blow-off, while when the ring electrode

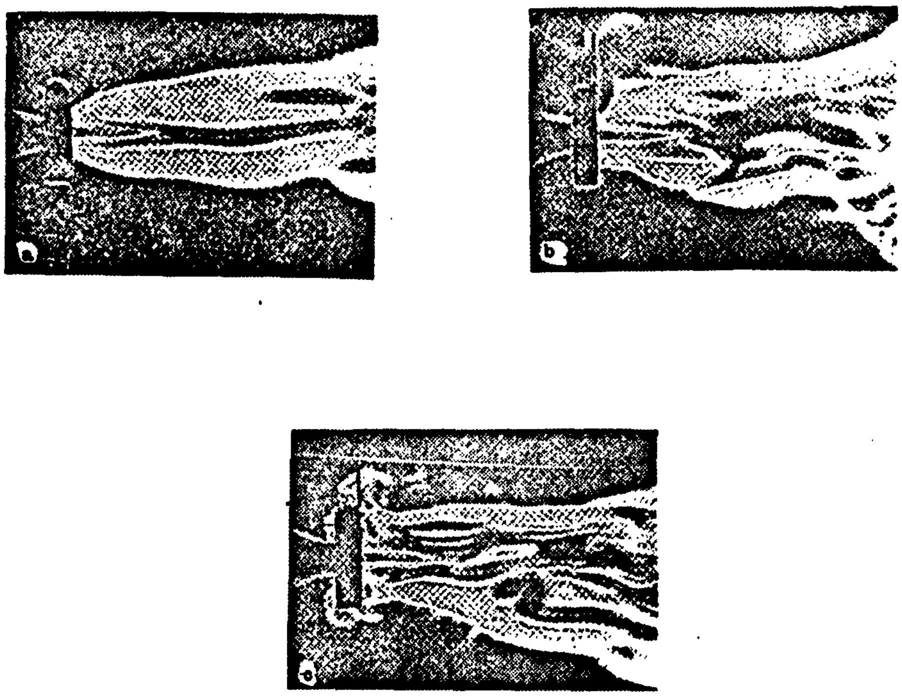

Fig. 3. Photographs of a propane-butane flame obtained by a shadow device with a filament of 0.16 mm; burner diameter 8 mm; fuel-air ratio 5%; gas flow 4 cm^3 (NTP)/sec., exposure 1/100 sec: a) u = 0; b) u = -20 kv; c) u = 20 kv, the flame begins to blow-off from the burner rim.

far from the burner rim a change of polarity does not change the nature of the influence of the field. Calcote and Pease [1] observed a similar phenomena with an increase of the strength of the positive field. They discovered that with a negative ring electrode, the field at first reduces its stability limits and, beginning with a certain voltage (close to 8000 v) the flame stability increases almost the same as a field of opposite polarity. From this Calcote and Pease proposed that with high field strengths not only is the mechanical influence of the field on the flame front exhibited but also, possibly, the ionization and excitation of gases in the field.

In our case, such an explanation is obviously not possible. Actually, first of all we observed a decrease of flame stability at much higher strengths than in the mentioned article [1] and, second, the flame stability improved with an increase of electrode spacing, i.e., with a decrease of field strength.

An interesting picture is found by observing schlieren-images of a flame with an electrical field applied to it. Photographs (Fig. 3) show that the field exerts a strong influence on the nature of the gas flow.

Analyzing the results of the tests, we can propose the following. Since in the flame there are charged particles of both signs, the field applied to it causes two flows of opposite directions. In the case of a negative central electrode, positive ions stream towards it, slowing down the flow at the walls of the burner where the distance between the flame front and central electrode is the smaller and the force of the electrostatic effect is greatest. This impedes flame blow-off [2] and increases its tendency to pass into the burner, which is first what we observed in our series of tests. The movement

of negatively charged particles — electrons — directed towards the ring electrode, as a result of their small mass, is less strongly expressed but it changes the condition for mixing of air in the flame from the surrounding medium (Fig. 3b). Mixing in this case is probably decreased, since with a certain increase in height of the ring electrode when the flow of gases to the ring is observed further from the burner rim and has less influence on mixing in this area, the velocity of the blow-off with application of a field increases more strongly than when h = 0. This is completely understandable since we worked primarily with rich mixtures for which the mixing of air greatly increases the flame stability.

With opposite polarity of the electrodes, positive ions, effected by the electrical field, are directed towards the ring and carry along a significant amount of gases of the flame (Fig. 3c). Reasoning analogously, we can conclude that worsening of the air mixing and an increase in the velocity gradient at the wall of the burner should lead to flame blow-off. This can be prevented only by a relatively weaker movement of electrons toward the central electrode, decreasing the velocity gradient at the wall of the burner, but this proves to be insufficient. Flame blow-off occurs. Placing the ring at a greater distance, the increase of the flow-velocity gradient at the walls of the burner because of the movement of positive ions is obviously not so high, the mixing of air at the burner rim improves, and as a result of the influence of the movement of electrons toward the central electrode and the inhibiting of the mixture flow caused by this at the walls of the burner the stability of the flame is improved somewhat.

Further investigation of the influence of an electrical field on

blow-off characteristics was conducted in a 27 mm diameter brass burner placed in a chamber where lower pressure was maintained by a vacuum pump. In these tests the fuel was a propane-butane mixture, with air as the oxidizer. The burner was protected by a quartz covering into which was placed a ring which served as the negative electrode. The burner itself served as the second electrode which was grounded. It was assumed that with a lowering of pressures the effect of applying the field would be more substantial than at atmospheric pressure. However, because of breakdown there also had to be a decrease in the voltage.

With a removal of blow-off characteristics at pressures of 500, 300 and 200 mm Hg there was no noticeable influence of the 5.3- and 2-kv voltage applied to the ring electrode; this voltage is close to breakdown voltage under these conditions. Only with blow-off of a flame of an over-rich mixture did application of a voltage of even 1 kv lead to the development of a stably burning rotary polyhedral flame. With experimentation on this installation with certain other burners there was no detected influence of the electrical field on blow-off characteristics.

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